The BIOLOGY *of* SEA TURTLES

Volume II

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16 Sea Turtle Husbandry

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CONTENTS

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16.1 INTRODUCTION

Sea turtle husbandry is the care and maintenance of sea turtles through scientific and judicious use of resources. Caring for turtles in captivity presents some problems, whether rearing them for research and conservation, public display (zoos and aquaria), or other commercial purposes. Sea turtles, in general, are sensitive to temperature variation; can be aggressive when crowded; are long-lived; and can reach great sizes, requiring large accommodations. Even if the sea turtles' natural physical environment can be artificially duplicated in captivity, general biological information is still lacking. For instance, little is known about the wild pelagic (early) life stages of all species, including basic information such as diet and feeding, growth, activity levels, and natural survival, all of which are fundamental parameters if one is to maintain turtles in captivity from hatchlings. Despite the lack of basic biological knowledge on sea turtles, many facilities have reared sea turtles in captivity with varying degrees of success. Much of what is known was learned through trial and error over decades of work. Available information on specific rearing practices is limited. Even with missing biological information, there is no reason to believe that sea turtles cannot be successfully reared and maintained in captivity by simply following sound animal husbandry practices.

The largest biological obstacles to sea turtle rearing are diet and disease. Green (*Chelonia mydas*) (Wood, 1991; Huff, 1989; Lebrun, 1975), loggerhead (*Caretta caretta*) (Caillouet, 2000; Buitrago, 1987), Kemp's ridley (*Lepidochelys kempii*) (Caillouet, 2000; Fontaine et al., 1985; 1988), and hawksbill (*Eretmochelys imbricata*) (Glazebrook and Campbell, 1990; Brown, 1982; Gutierrez, 1989) turtles have all successfully been reared in captivity. Attempts have been made to rear leatherback hatchlings (*Dermochelys coriacea*) in captivity with limited success (Jones et al., 2000; Voss et al., 1988), and little information is available on captive rearing of the olive ridley (*Lepidochelys olivacea*) (Rajagopalan et al., 1984) and flatback (*Natator depressus*).

Many facilities, throughout the world, have experimented with rearing sea turtles in captivity, some with more success than others (Wood, 1991; Stickney, 2000). In the 1960s and 1970s, rearing sea turtles in captivity was synonymous with farming or ranching, primarily as a response to new laws protecting the wild take of sea turtles (Stickney, 2000). In the 1980s, there was a shift in focus from farming to research (Huff, 1989; Caillouet, 2000; Caillouet et al., 1997). Most facilities are now rearing sea turtles for public display or conservation (Ross, 1999), with efforts directed toward wild stock enhancement.

In 1977, the National Marine Fisheries Service, Sea Turtle Facility (NMFS STF), was established in Galveston, TX. The NMFS STF is a U.S. federal government facility dedicated to rearing sea turtles for research, specifically aimed at reducing sea turtle bycatch in the U.S. commercial fisheries (Mitchell et al., 1989). Large sample sizes are required for certifying and evaluating potential sea-turtle-saving measures, thus necessitating the rearing of hundreds of sea turtles each year. The NMFS STF also rears loggerheads and Kemp's ridleys for research on physiology, tagging, and genetic and population dynamics. This chapter uses the NMFS STF as a model facility to describe successful sea turtle husbandry techniques.

16.2 REARING FACILITIES

Creating a suitable environment in which to raise sea turtles requires the ability to house the turtles in a controlled environment. In the U.S., all sea turtle species are protected animals, and there are specific state (Florida Fish and Wildlife Conservation Commission [FWC], 2002) and federal (U.S. Fish & Wildlife Service, 1973) government guidelines regulating sea turtle holding and rearing operations, including tank dimensions, feed, and environmental requirements. Tank layout and water delivery systems used to hold sea turtles are varied and include ocean pens constructed along shorelines; large concrete tanks with flow-through water delivery; or many small tanks connected to complex recirculating biofilter systems. The layout of the NMFS STF has been described previously in several publications (Caillouet, 1988; 2000; Fontaine et al., 1985; 1988; 1990) and consists of a static water system containing twenty 5940-l fiberglass raceways. The raceways are contained in a temperature-controlled warehouse-style building.

16.2.1 Tank Selection

The physical dimensions and material in which the turtles are contained are determined by the size and activity of the species cultured. Smooth-surfaced, unfurnished containers that are large enough to allow for unimpeded movement and complete submersion of the turtle are the minimum requirements. Sea turtles will eat artificial corals, fish, standpipes, plumbing, and other tank furnishings. Great care should be exercised when placing a turtle in a tank to ensure that it cannot be injured through impact with or ingestion of tank furnishings. Plexiglas is easily scratched by sharp claws, and this should be taken into consideration when a turtle in placed into a tank for public display in a zoo or aquarium. Provision for separation of turtles and their waste products should be addressed either by using a physical barrier or by constant mechanical removal of waste. As turtles grow, they require more space, necessitating progressively larger accommodations (Table 16.1). Turtles must be reared in individual containers to prevent injuries from contact with other turtles; this may include separate tanks or common compartmentalized tanks. Aggressiveness varies among species. All species can and will bite each other when housed together in the same tank (Glazebrook and Campbell, 1990; Leong et al., 1989; Klima and McVey, 1982). The NMFS STF maintains sea turtles in a variety of independent rearing containers housed in fiberglass-reinforced, polyester resin, gel-coated fiberglass tanks and raceways (Caillouet, 2000) (Figure 16.1).

16.2.2 Tank and Raceway Preparation

Prior to stocking, raceways are drained and thoroughly hand-scrubbed using Scotchbrite®-type (3M Home Care Division, St. Paul, MN) nylon abrasive pads. The raceways are then filled completely with seawater. Two gallons (7.58 l) of bleach (sodium hypochlorite) is added to the approximately 6814 l of water. The bleach is allowed to disinfect the tank for 24 h. Raceways are then drained and rinsed with freshwater. If the surface of the tank is porous or scratched, high-pressure washing (freshwater at 1500–1800 psi) may also be done to remove algae and other detritus imbedded in the gel coat. The raceways are refilled with seawater and allowed to soak for 24 h. Raceways are again drained, rinsed with freshwater, and are then ready for stocking.

16.2.3 Container Preparation

16.2.3.1 Hatchling Rearing Containers

Plastic flowerpots are used to house hatchlings for the first 60 days at the NMFS STF. Flowerpots are cleaned and disinfected prior to the arrival of new hatchlings. The pots are allowed to soak in a bleach solution (2:l of sodium hypochlorite and 115:l of freshwater) for 15–30 min. Each pot is hand scrubbed inside and out with a Scotchbrite-type nylon abrasive pad to remove all traces of dirt and algae. The pots are dipped into a bleach solution (1:15), rinsed in freshwater, and allowed to air dry. Clean pots are stored in an insect- and dust-free container until they are ready for use. Just prior to stocking, the pots are soaked in seawater for 24 h followed by a freshwater rinse.

16.2.3.2 Post-Hatchling and Juvenile Rearing Containers

Modified milk crates are used to house turtles from 60–90 days until 10–11 months, and custom-built hanging cages are used from 11–22 months at the NMFS STF (Caillouet, 2000). Crates and cages are removed from the facility, and every surface is cleaned with a high-pressure washer (freshwater at 1500–1800 psi) to remove all traces of dirt and algae. The containers are placed back into the raceways and are

TABLE 16.1
A Comparison of Actual and Recommended Rearing Space Sizes and Stocking Densities

Facility/Agency	Turtle Size	Turtle Age (months)	Tank/Pen/ Container Size (m²)	Tank Volume (l)	Number Turtles/Tank	Surface Area/Turtle (m²)	Water Vol./Turtle (l)	Stocking Density (g/l)
NMFS STF	10–60 g	0–3	Cont., 0.02	2195	200	0.02	11	1.0–5.5
	60–500 g	3–11	Cont., 0.11	3292	80	0.11	41	1.5–12.2
	0.5–7.0 kg	12–24	Cont., 0.46	5486	14	0.46	392	1.3–17.9
	7.0–25.0 kg	25–48	Cont., 1.3	5940	7	1.30	849	8.2–29.4
	5.0–25.0 kg	20–48	Pen,[a] 142.7	178,734	10–30	4.7–14.2	5958–17,873	0.8–1.4
CTF	4.1 kg[b]	14[b]	Tank[b]	130,000[b]	100[b]		1300	3.2
	4.1 kg[b]	14[b]	Tank[b], 7.1	3000[b]	50[b]	0.14	60	68.3
	21.6 kg[b]	44[b]	Tank[b], 7.1	3000[b]	10[b]	0.71	300	72
	90–200 kg[c]		Pond/pen[c]			4.0–6.5[c]		
	24.7 kg[d]	36–84[j]	Pond, 207[d]	289,800	37[d]	6[d]		3.2
Los Roques	Hatchling	0–6[e]	Tank[e], 1.3[e]	260	30[e]	0.04	32.8	8–10[e]
	Post-hatchling	>6[e]	Pen[e]		1[e]	3.0[e]		0.5[e]
FWC	<5 cm[f,g]	0–1[g]	0.09[g]	29[g]	1[g,i]	0.09[g]	29	0.7[h]
	>5 cm and <10 cm[f,g]	1–6[g]	0.09–2.22[g]	29–698[g]	1[g,j]	0.09–2.22[g]	29–698	0.7–16.5[h]

(continued)

	<60 cm[f,g]	6–40[g]	2.32–5.01[g]	1816–4709[g]	1[g,j]	2.32–5.01[g]	1816–4709	6.5–1.8[h]
	>90 cm[f,g]	>40[g]	4.74–11.42[g]	4709–14,168[g]	1	4.74–11.42[g]	4709–14,168	
Costa Rica	4–24 cm[k,l]							
	15g–24.2 kg			21,000[l]	60[l]		333	0.05–9.9[l]

Note: Unreferenced figures were calculated based on referenced data. NMFS STF (*Caretta caretta* [Cc], *Lepidochelys kempii* [Lk]).

[a]NMFS Panama City, Florida facilities (Cc).
[b]Data from CTF (*Chelonia mydas* [Cm]). (From Ross, J.P. 1999. Ranching and captive breeding sea turtles: Evaluation as a conservation strategy, pp. 197–201, in: *Research and Management Techniques for the Conservation of Sea Turtles*. K.L. Eckert et al. (eds.). IUCN/SSC Marine Turtle Specialist Group Publication No. 4. With permission.)
[c]Data from CTF (Cm). (From Wood, F. 1991. Turtle culture, in: *Production of Aquatic Animals*. C.E. Nash (ed.). World Animal Science, Elsevier, Amsterdam. With permission.)
[d]Data from CTF (Lk). (From Wood, J.R. and F.E. Wood. 1988. Captive reproduction of Kemp's ridley *Lepidochelys kempii*. *J. Herpetol.* 1:247–249. With permission.)
[e]Data from Los Roques (*Eretmochelys imbricata* [Ei], Cm). (From Buitrago, J. 1987. Rearing, with aim of repopulating, of three marine turtle species at Los Roques, Venezuela. *Mem. Soc. Cienc. Nat. La Salle.* 127–128:169–201. With permission.)
[f]Straight carapace length (SCL). (From Bolten, A.B. 1999. Techniques for measuring sea turtles, pp. 110–114, in: *Research and Management Techniques for the Conservation of Sea Turtles*. K.L. Eckert et al. (eds.). IUCN/SSC Marine Turtle Specialist Group Publication No. 4. With permission.)
[g]Data were calculated using NMFS STF 1996 year-class Texas loggerhead data. (From Florida Fish and Wildlife Conservation Commission. 2002. Unpublished. Marine turtle conservation guidelines: Section 4 — holding turtles in captivity. Tallahassee, Florida. With permission.)
[h,i]Add 25% surface area for each additional turtle.
[j]Add 50% surface area for each additional turtle.
[k]Method of carapace measurement is unknown.
[l]Ei data from Costa Rica. (From Gutierrez, W. 1989. Experiences in the captive management of hawksbill turtles (*Eretmochelys imbricata*) at Isla Uvita, Puerto Limon, Costa Rica, pp. 324–326, in: *Proceedings of the Second Western Atlantic Turtle Symposium*, Oct. 12–16. L. Ogren (ed.). NOAA Tech. Mem. NMFS-SEFC-226. With permission.)

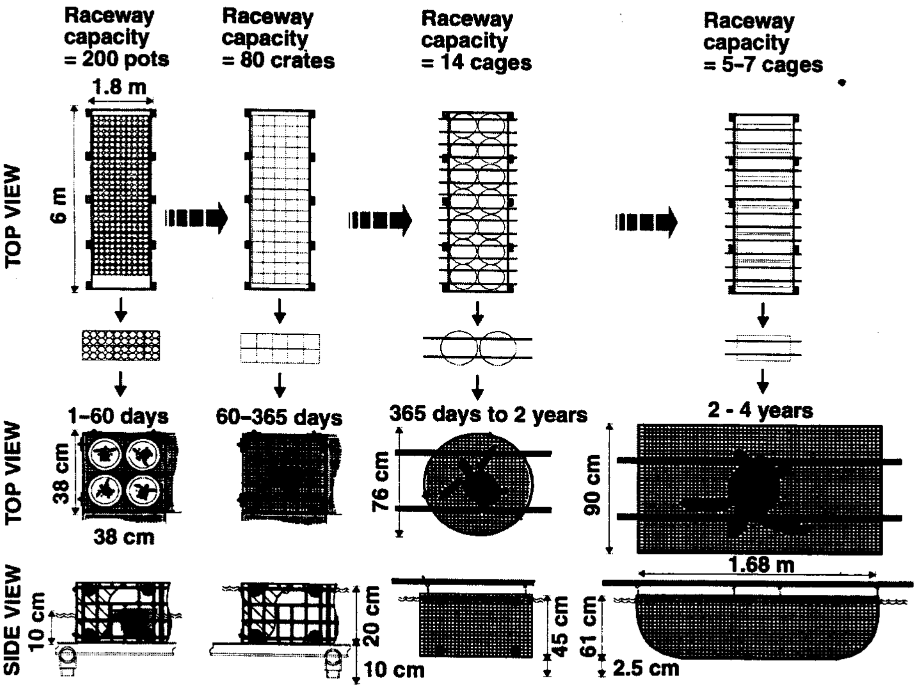

FIGURE 16.1 Progression of rearing container size with sea turtle growth at the NMFS STF. A common raceway tank is used to house 5–200 turtles. (Modified from C.W. Caillouet, Jr. 2000. Sea turtle culture: Kemp's ridley and loggerhead turtles, pp. 788–798, in: *Encyclopedia of Aquaculture*. R.R. Stickney (ed.). John Wiley & Sons, New York, 2000, 786. With permission.)

bleached at the same time the raceways are disinfected. The crates are soaked in raceways filled with the bleach solution for 24 h. The crates are rinsed with freshwater followed by an additional 24 h soak in seawater. The containers are again rinsed with freshwater and stored dry until they are ready for use. Just prior to use, the containers are soaked in seawater for 24 h followed by a freshwater rinse. A new batch of hog rings (Caillouet, 2000) is applied to the bottom of the cages annually to replace those that rusted off or became loose during the previous year. New nylon cable ties (Caillouet, 2000) are used to suspend the cages. Crates and cages are stored dry until they are ready for use.

16.3 SEAWATER SYSTEM

The NMFS STF relies on a natural seawater system consisting of a beach pump, sump, and water storage tanks (Caillouet, 2000; Fontaine et al., 1985). Water is drawn directly from the Gulf of Mexico.

16.3.1 Water Treatment and Storage

The NMFS STF uses four 26,000-l and two 38,000-l insulated fiberglass tanks to store seawater (Caillouet, 2000). Each of the four small tanks contains a quartz immersion heater (14,000 W). Each heater is connected to a temperature-control unit, allowing the tanks to be adjusted independently. There is no active filtration or treatment of any kind in the seawater system. The well points below the sand remove large particles from the water. Settling in the sump and large holding tanks removes most particulate matter, suspended algae, larvae, and some bacteria from the seawater. Further settling in the eight smaller water storage tanks removes the remainder of suspended sediment. The NMFS STF uses approximately 37,854–68,137-l of new seawater daily. Wastewater is discarded into the city of Galveston sanitary sewer system.

From late September through April, the NMFS STF heats seawater. Seawater is heated to approximately 38–43°C in three of the four 26,000-l storage tanks. Hot water is mixed with ambient water 10–26°C by manipulating hot- and cold-water valves to achieve an incoming water temperature of 26–30°C with a target of 28.5°C.

16.4 ENVIRONMENTAL PARAMETERS

The STF uses natural seawater in a static system where water is exchanged in each tank three to six times per week. Three water quality parameters are monitored and recorded daily: temperature, salinity, and pH.

16.4.1 TEMPERATURE

Maintaining a constant and acceptable temperature is critical for growth and for preventing disease in sea turtles (Haines and Kleese, 1977; Leong et al., 1989; Caillouet et al., 1997). Water temperature at the NMFS SFT is maintained within the range of 26–30°C (Figure 16.2). Water temperature is maintained by mixing warm (heated) and cold (ambient) seawater to the desired temperature. Air temperature over the tanks is also controlled using forced-air heaters in cool months and ventilation fans in hot months. The air temperature in the facility is 29–32°C at night (maintained by heaters in cool months) and is reduced to 24–26°C during the day to provide a more comfortable environment for captive rearing staff. In months where heating the air is not required, the facility remains at a constant 28°C day and night with the assistance of exhaust fans and cross-flow ventilation. Temperature is measured with a thermometer, accurate to 0.5°C.

When the temperature falls below 22°C, turtles that are normally maintained at 26–30°C will slow or cease feeding. At temperatures above 32°C, water quality becomes an issue because algae and bacteria populations can rapidly multiply in the raceways. Sea turtles that are normally maintained at temperatures 24–25°C may tolerate temperatures as low as 20°C before exhibiting signs of reduced metabolic activity. Sea turtles should be maintained at 20–30°C (FWC, 2002), preferably in the range of 25–30°C. Even short periods of water temperatures below 22°C combined with shorter photoperiods in winter months can trigger carapace lesions in loggerheads (Higgins, unpublished data). The carapace lesions can be characterized by a white fluffy exudate that appears to grow from the eroding neural and postmarginal scute spines. Outbreaks are directly related to water temperature and water quality. The lesions, if left untreated, result in keratin

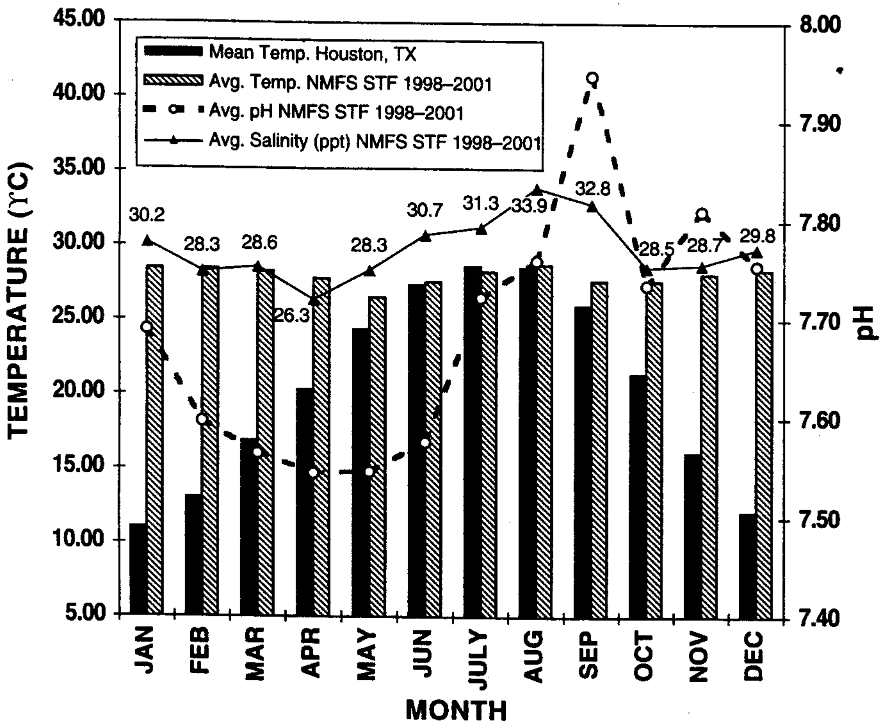

FIGURE 16.2 Graphical comparison of average water temperature, salinity, and pH readings over a 4-year period (1998–2001) in the NMFS STF. Water temperature remains at a constant 27–29°C despite wide-ranging ambient outside air temperature (Data from NOAA, National Climatic Data Center Archives). pH fluctuates with biomass in rearing tanks, whereas salinity remains in the range of 26–34 ppt. Typically, the biomass peaks in the NMFS STF in early May when more than half of the loggerheads are shipped to Florida for research. Note the steady decline in pH from January through May, followed by a rapid increase in pH mid-May, which correlates to the departure of the large turtles. pH peaks in September just prior to the arrival of loggerhead hatchlings.

loss and eventual bone erosion and degeneration. Histology results on carapace samples showed no infectious agents. Similar lesions have been reported on captive-reared loggerheads with bacterial and fungal organisms present (Neiffer et al., 1998; Leong et al., 1989).

16.4.2 Salinity

Salinity at the NMFS STF is maintained between 14 and 32 ppt. Normal natural salinity of NMFS STF incoming water is 26–30 ppt. When salinity exceeds 34 ppt, freshwater is added to the water storage tanks to dilute hyper-saline water. Optimal salinity for maintaining healthy captive sea turtles is 20–35 ppt (FWC, 2002). Sea turtles may be temporarily maintained at salinities outside the normal range for therapeutic purposes as prescribed by a veterinarian. Low salinity may be helpful for removing parasites and fouling epibiota such as barnacles. Sea turtles can withstand short periods of freshwater (0 ppt) (Walsh, 1999). Freshwater treatments of up to 2 weeks have been used to treat floating–bloating problems with limited success, with no observable detriment to the turtles' health. A nonprescribed salinity of less than 14 ppt for a period of more than 2 weeks would require the addition of salt to the storage tanks to increase salinity. Salinity should be measured with a refractometer accurate to 1 ppt.

16.4.3 pH

pH is an indicator of water quality. As water quality degenerates from the accumulation of turtle waste products, pH decreases. Normal incoming NMFS STF seawater has a pH of 7.9–8.2. A pH reading of less than 7.4 indicates that a raceway is in need of cleaning. The normal pH of a clean raceway containing turtles ranges from 7.5 to 8.1. pH is controlled by cleaning and changing water. Average pH decreases as biomass and bioload increase in a raceway. Optimal pH for sea turtles is 7.5–8.5 (FWC, 2002). pH is measured with a digital pH meter accurate to two decimal places.

16.4.4 Light

The majority of light in the NMFS STF comes from the translucent fiberglass panels that make up a portion of the roof (15–1.2 m × 2.4 m panels). Fluorescent lighting (2 × 40 W × 15 fixtures) is used approximately 48 h/week to supplement sunlight. The daily amount of light the turtles receive is dependent on the natural available sunlight in Galveston, TX. The amount of actual ultraviolet (UV) light that reaches the sea turtles in the NMFS STF through the fiberglass panels is unknown. No health problems have been identified and associated with a lack of suitable light. Kemp's ridleys held in captivity for more than 1 year and loggerheads held in captivity for more than 2 years tend to be lighter in complexion than their wild counterparts. Sunlight is important in reptiles for the synthesis of vitamin D_3. A lack of suitable light may require dietary supplementation.

Experimentation with different quality and quantities of artificial light (both full-spectrum fluorescent lights, limited-spectrum lights [grow lights], and metal halide lights [5000 K]) as treatments for carapace lesions or infections and floating–bloating has been tried without success. Short periods of direct sunlight may help treat topical fungal lesions of the skin (Fontaine et al., 1988). Natural diurnal light patterns should be replicated for turtles housed in captivity. Excess light and nontherapeutic direct sunlight should be avoided to control algae growth, and to prevent elevated water temperature and sunburn.

16.5 HATCHLING SELECTION

Every attempt should be made to acquire captive stock bearing good genetic lineage, ideally from many different nests. Avoiding physical deformities from the onset will pay dividends in the end. Turtles with visible deformities may exhibit stunted and slow growth, and feeding and behavioral problems. In the U.S., both federal and state laws may prevent the public display, release, or euthanization of congenitally deformed turtles. When hatchlings are selected, three criteria need to be addressed: physical deformities, weight and size, and activity.

16.5.1 Physical Deformities

Each hatchling should be carefully inspected for eye deformity (blindness, lesions), cross-beak, curvature of the spine, and carapace deformities or abnormalities (extra or missing scutes). Hatchlings with visual physical deformities should be avoided. Spinal curvature may be very subtle in hatchlings but can develop into crippling deformities in older turtles.

16.5.2 Weight and Size

Hatchlings that are light in weight or excessively heavy may have genetic abnormalities and should be avoided. Small, underweight hatchlings are an indication of poor development or dehydration.

16.5.3 Activity

Hatchlings that are selected should be active and exhibit vigorous climbing and crawling activity. Lethargic hatchlings should be avoided.

16.5.4 Quarantine

Hatchlings are quarantined for 60 days when they arrive at the NMFS STF. The new hatchlings are housed in a raceway separate from the other turtles and care is taken to prevent any cross contamination between raceways. When space permits, each clutch of hatchlings is maintained together to monitor variations in survival and growth. Staff members wear latex surgical gloves when handling hatchlings for the first 30 days. Captive-rearing staff members are required to wash their hands before handling turtle feed and any measuring equipment is cold sterilized before and after use on new hatchlings. After 60 days, hatchlings can be combined in raceways. The NMFS STF also maintains a full quarantine facility for chronically and terminally ill sea turtles. A minimum quarantine period of 90 days is required before a rehabilitated turtle is placed in the captive-rearing facility. The introduction of a rehabilitating turtle into a raceway containing healthy captive reared stock is not recommended.

16.6 DIET, FEEDING, AND GROWTH

16.6.1 Diet

Sea turtles are opportunistic omnivores, consuming whatever is available. Wild turtles have a highly varied diet that changes with life stage (Bjorndal, 1997). Hatchlings and pelagic turtles typically consume what is available at the surface, whereas older, larger benthic turtles consume food thoughout the water column with emphasis on benthos (Bjorndal, 1997). Gut content analysis studies have been done on all sea turtle species cataloging food items consumed (Bjorndal, 1997), but little is known about actual wild feeding rates. In captivity, overfed turtles and turtles fed *ad libitum* are prone to obesity, fatty degeneration of the liver (Solomon and Lippett, 1991), and bloating.

Captive sea turtle diets vary considerably, ranging from natural foods (whole fish) to commercially prepared dry pelleted diets. Blends of natural foods (i.e., fish, shrimp, squid, crab, scallops), often supplemented with vitamins, are popular diets in zoos and aquaria. Blends may be prepared fresh each day or prepared in bulk and kept frozen until needed. Mixtures of natural foods may contain gelatinous binders to keep food from dispersing in the water prior to consumption by the sea turtles (Jones et al., 2000; Cong and Wang, 1997). To produce the same growth as dry pelleted foods, wet food is offered at a rate of up to five times that of dry food to compensate for the difference in moisture content. Wet feed rates vary from maintenance diets of 1% body weight per week (Higgins, unpublished data) to production–growth diets of 12–15% per day (Sumano Lopez et al., 1980). Feeding to satiation has also been reported with leatherback hatchlings (Jones et al., 2000).

The NMFS STF feeds a natural maintenance diet (whole mackerel) to loggerheads at 1% body weight per week when trying to maintain turtles at a specific size for research. Fasting days are common in aquaria. One or two days without food helps promote an appetite and may help maintain water quality. The NMFS STF feeds six days per week. Turtles maintained in aquaria with other animals may become very aggressive and compete for food. Turtles may attempt to consume all food introduced into the tank, resulting in overfeeding and leading to obesity. Feeding demonstrations are popular attractions at aquaria, and aggressive feeding by turtles may put divers at risk of injury. It may be necessary to distract or isolate turtles while the rest of the tank is fed.

Most large captive-rearing facilities feed some form of commercially prepared pelletized feed consisting of 25–45% crude protein, and 3.9–12% fat, 3.22–8.58% fiber (Caillouet et al., 1989; Wood and Wood, 1980; Wood, 1980). Higher protein levels result in greater growth (Wood, 1980; Caillouet et al., 1989). The protein source and content of the feed typically drives the feed cost; higher protein content commands a higher price, and protein from fish meal is more expensive than plant protein. Although weight gains of turtles fed fish versus plant protein sources are similar (Higgins, unpublished data), those turtles fed the fish meal source appeared to be more robust (Higgins, unpublished data). Diets containing soy products, especially those utilizing soy as the primary protein source, may increase estrogen levels in the blood (Shaw et al., 1989). Soybeans contain high levels of phytoestrogen. Increased phytoestrogen levels in humans have been linked to liver disease and reproductive problems (Shaw et al., 1989).

Several commercially available diet formulations have been successfully used over the years (Wood, 1991; Wood and Wood, 1980; Caillouet et al., 1989). Currently, the NMFS STF turtles are fed Aquamax® 500 Grower (PMI Nutrition International, Inc., Brentwood, MO). This is a dry, 4.7-mm (3/16 in.) diameter extruded pellet, which is small enough to be consumed by all sized turtles. The pellets float and remain intact in seawater. Pellet food should be bought in small quantities and kept frozen until use to preserve freshness, and prevent mold and rodent and insect infestation. Wet diets such as squid and fish create water quality problems and should be avoided for small turtles. Diets composed primarily of squid are high in phosphorus and may not contain sufficient calcium to meet the needs of the animal (Goldman et al., no date); some form of calcium supplementation may be required. Larger pellet feed is available for larger turtles, but often, feeding whole fish or squid is more convenient. Squid should be avoided as a long-term diet for sea turtles. However, squid is readily accepted by most species of turtles in captivity and is particularly good for coaxing wild rehabilitating turtles to eat. Several wet–semiwet gel diets have been developed specifically for hatchling leatherbacks (Jones et al., 2000; Cong and Wang, 1997), with limited success.

16.6.2 Feeding

The NMFS STF uses floating pellets for the first 2 years, and switches to a natural fish-based diet for larger turtles. Starting on day 10, each hatchling is offered one pellet, which represents approximately 2% of its body weight. Pellet feeding rates vary from 1.19 to 1.99% body weight/day (Figure 16.3). Each week the number of pellets is increased by one until each turtle receives 12 pellets twice per day. Starting in week 2, turtles are fed twice per day. Two smaller feedings are superior to one large single feeding, from a growth and water quality standpoint (Caillouet et al., 1989). Starting in week 25, calibrated feeders are made based on a percentage of

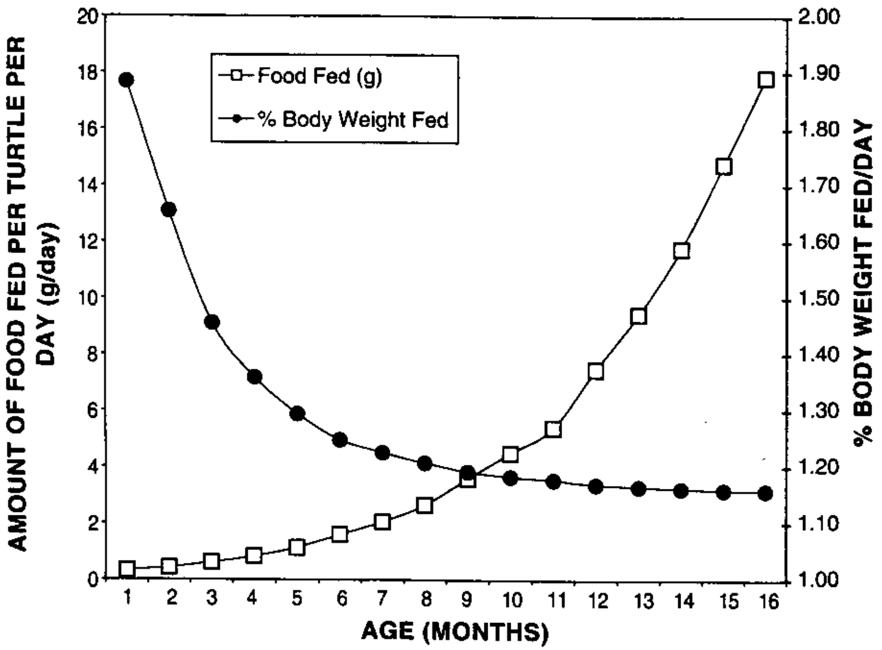

FIGURE 16.3 Graphical comparison of amount of food given and percentage of body weight fed per day. Percentage of body weight fed decreases with growth and amount of food given. Feeding rate was calculated using the NMFS STF feeding formula on the basis of the average weight of the 1995–2000 year class of Kemp's ridley sea turtles.

body weight as determined by a formula developed by the NMFS STF for Kemp's ridleys. The formula is also used for loggerheads. The food is scooped from a bucket by hand, with the feeder being the unit of measurement. Each turtle is given one scoop, twice per day. The NMFS STF feeding formula is

$$Y = 0.12515 + [(11.502x)/1000]$$

where x = turtle weight in grams and Y = amount of feed per turtle per day in grams.

Each turtle is individually fed, ensuring that all turtles get approximately the same amount of food.

16.6.3 Hatchlings

NMFS STF hatchlings are not fed until they are 10 days of age. Often, hatchlings are physically excavated from the nest, thus, they have not expended any energy emerging, crawling, or swimming. At rearing facilities, hatchlings are housed in relatively confined containers where swimming motion and energy expenditure are minimal; a longer time period is required for them to completely absorb the internal yolk sac. A delay in feeding gives the hatchlings an opportunity to partially absorb the internal yolk before they take in external nutrition. Feeding hatchlings prior to yolk sac absorption can result in constipation, lethargy, dehydration, and sudden death (Leong et al., 1989; Fontaine and Williams, 1997). Necropsy results on hatchlings fed prior to yolk sac absorption show compaction of food in the gut caused by the yolk sac displacement of internal organs (Leong et al., 1989; Fontaine and Williams, 1997).

16.6.4 Post-Hatchlings

Turtles are fed twice per day, at the beginning and end of the normal business day, at 7:30 a.m. and 4:00 p.m. The turtles are allowed 15–30 min to consume the morning feeding before the tanks are drained and cleaned. Hatchlings typically take longer to consume their food than the larger turtles, and are given a minimum of 30 min to consume food presented. On average, a healthy sea turtle will consume 100% of food offered within 15 min.

16.6.5 Growth and Survival

Sea turtle growth is directly related to food consumed and is exponential (Caillouet et al., 1989; 1997; Fontaine, unpublished data) (Figure 16.4). Survival rates are variable among different species and facilities and are a function of genetics and husbandry practices (i.e., water quality, feed, disease prevention and treatment). Most mortality occurs at the hatchling stage, and mortality levels off by month 6. Facilities with steep and rapid growth curves also have lower survival; this may be a function of water quality related to feeding. Much of the published data are from large-scale captive rearing operations, and the same growth–survival trend may not be present in smaller facilities such as zoos and aquaria. Sea turtle growth can be accelerated or maintained by varying the amount of food offered.

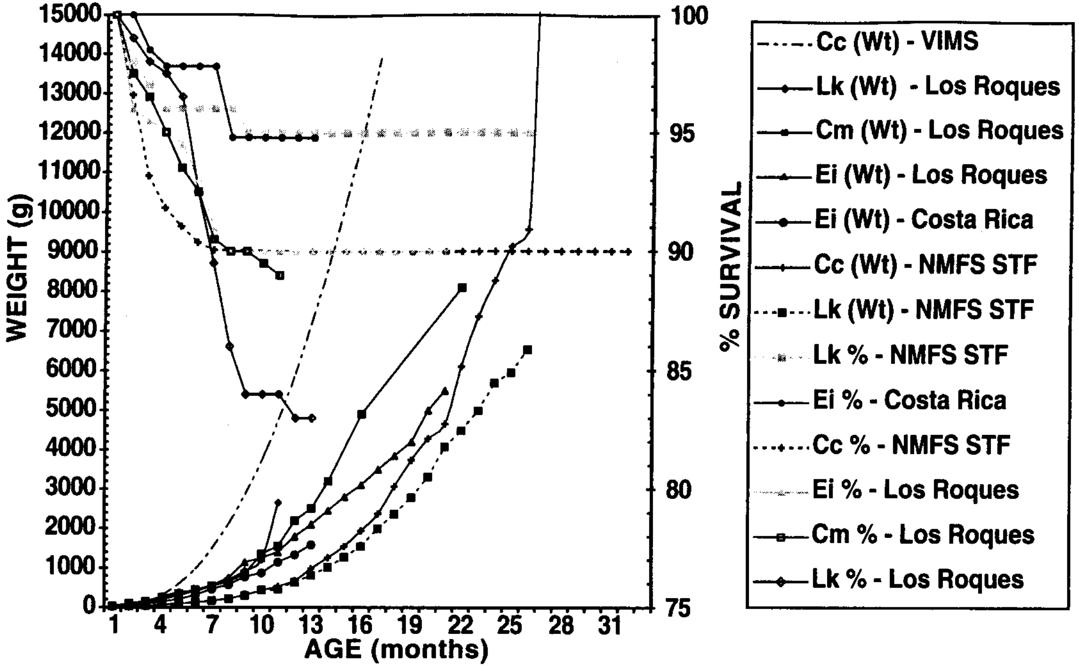

FIGURE 16.4 Comparison of growth and survival of captive sea turtles at different rearing facilities. The Virginia Institute of Marine Science (VIMS) curve was extrapolated from two data points (from Swingle, W.M. et al. 1993. Exceptional growth rates of captive loggerhead sea turtles, *Caretta caretta*. *Zoo Biol.* 12:491–497, with permission). The Los Roques data were extrapolated (from graphs in Buitrago, J. 1987. Rearing, with aim of repopulating, of three marine turtle species at Los Roques, Venezuela. *Mem. Soc. Cienc. Nat. La Salle.* 127–128:169–201, with permission). The Costa Rican data were calculated from a table (from Gutierrez, W. 1989. Experiences in the captive management of hawksbill turtles (*Eretmochelys imbricata*) at Isla Uvita, Puerto Limon, Costa Rica, pp. 324–326, in: *Proceedings of the Second Western Atlantic Turtle Symposium*, Oct. 12–16. L. Ogren (ed.). NOAA Tech. Mem. NMFS-SEFC-226, with permission). The NMFS STF data are an average of data taken on 6 year classes from 1995 to 2000. Cc = *Caretta caretta*; Lk = *Lepidochelys kempii*; Cm = *Chelonia mydas*; Ei = *Eretmochelys imbricata*.

16.6.6 Feeding Problems

Overfeeding of loggerheads and Kemp's ridleys with commercially prepared diets can cause buoyancy problems (bloating–floating). Bloating can be chronic, resulting in carapace–plastron deformities, rendering the turtle unfit for release and often leading to death. Even using the NMFS STF feeding formula, very careful monitoring of the turtles is required to ensure that an overfeeding situation does not arise. The amount of feed is increased or decreased from the formula amount on the basis of the appearance and activity of the turtles. Treatment of bloated turtles is still in the experimental phase and several parameters are being evaluated, including change of diet, change of water depth, increased rearing space, and devices to stimulate diving and benthic behavior (Higgins and Bustinza, unpublished data).

Food consumption is used as an index of turtle health. High-quality pellet feed floats and does not dissolve in the water, so any food remaining after 15–30 min is an indicator that feeding activity is abnormal. It is common for sea turtles to exhibit a period of slow eating activity in winter months or on overcast days. Sea turtles reared in a facility that is primarily lit by natural sunlight are photoperiod-sensitive. Slow eating behavior or a cessation of eating is a major concern and often is a symptom of a serious health problem. Turtles are observed during and after every feeding. Turtles that exhibit slow feeding are monitored, as are turtles that stop feeding. A turtle that shows no interest in food for 3 consecutive days is removed from the common tank and moved to an area of isolation, known as the STF first care area (FCA). The FCA is housed within the same building as the general rearing facility and is not a 100% quarantine area. The FCA contains a series of small individual tanks where turtles can be given specific medicinal treatments and water quality is therapeutically manipulated.

16.7 STOCKING DENSITIES

Stocking densities play a large role in sea turtle husbandry. Stocking densities combined with feeding ultimately determines water quality. Better water quality will most often be accompanied by a low stocking density. High stocking densities are usually indicative of tank culture, whereas low densities are found in pens. Four facilities were examined and stocking densities were determined directly from literature or calculated from available information. Stocking densities varied from 0.05–72 g/l (Table 16.1). Florida's FWC publishes guidelines for holding sea turtles in captivity (FWC, 2002). The FWC guidelines are primarily for facilities that maintain only a few turtles for research, public display, and rehabilitation. The FWC-recommended stocking densities are very conservative, and it would be difficult for large production facilities to economically meet these standards, even though they were created for the benefit of sea turtles and they should be viewed as an ultimate goal.

16.8 ROUTINE CLEANING

16.8.1 Turtles

Every other day, each tank is completely drained, rinsed with freshwater and refilled with fresh seawater. Every inside surface of the tank and rearing containers is hosed off. The turtles are sprayed with freshwater directly on all exposed surfaces, with particular emphasis on the carapace to remove any loose algae or molting carapace material. For the first 90 days, one-half city water pressure (approximately 30 psi) is used when spraying the turtles. After 90 days, the turtles are sprayed with full city water pressure (approximately 60 psi). Turtles are out of water for up to 30 min every other day during the cleaning process, but are not allowed to dry. Prolonged periods out of the water will cause carapace desiccation leading to scute peeling. Damage to carapace from desiccation may provide an entry path for bacterial and fungal infection. Small loggerheads are more sensitive to desiccation and scute peeling than Kemp's ridleys, greens, or hawksbills.

Although wild sea turtles naturally display varying degrees of epibiota, captive-reared turtles are susceptible to heavy and rapid biofouling, requiring periodic removal. Typically, captive and wild pelagic turtles lack access to a substrate on which to scrape away accumulating epibiota. Epibiotic buildup leads to hydrodynamic drag and increased weight, and can potentially impact swimming performance. Epibiotic buildup may also create a medium for bacterial and fungal infection. Smaller turtles may be more sensitive to buildup than larger turtles, especially hatchlings. In the wild, algae and settling larvae are possibly kept in check and removed from pelagic turtles by epibiotic crabs (Frick et al., 2000), a relationship that is most likely absent in the captive environment. Algae must be mechanically removed from captive turtles with scrub brushes. Nylon bristle brushes are disinfected prior to use and between each tank or group of turtles in a solution of bleach (sodium hypochlorite 2%) (1:4) or chlorhexidine (2% chlorhexidine gluconate) (1:4) followed by a freshwater rinse. Every effort is made to maintain the integrity of the independent environment in each tank by reducing the chance of cross contamination.

16.8.2 Rearing Containers

Uneaten food and waste that has settled on the bottom of the tank is directed by hose nozzle manipulation and city water pressure (60 psi) to the drain. To facilitate cleaning the raceway bottom, crates are moved along a polyvinyl chloride (PVC) support rack, which keeps the crates off the tank bottom (Caillouet, 2000). Cages are suspended off the bottom to facilitate cleaning and can be moved to gain access to the tank bottom. Once a month the inside tank surfaces and racks are hand scrubbed with a Scotchbrite-type nylon abrasive pad. Hand scrubbing is preferred to high-pressure washing. High-pressure washing tends to atomize waste material, creating a potential airborne tank-to-tank contamination problem. High-pressure washing (1500–1800 psi) may be used after tanks are disinfected.

16.9 DATA COLLECTION

Every hatchling is weighed and measured upon arrival at the NMFS STF. Every 28 days thereafter, a subsample of turtles from each year class is weighed and measured. At random, a minimum of 25 turtles are selected from each year class and those turtles are used to determine the feed ration. Four measurements are taken: weight, straight carapace length (notch to tip), straight carapace width (maximum), and body depth (maximum) (Bolten, 1999). An average weight is determined for the subsample and used to calculate the feeding rate for that year class. Weighing and measuring allows the captive-rearing staff a chance to carefully examine the sea turtles for any signs of problems. Each sea turtle is handled as little as possible to prevent injury to turtle and handler.

16.10 TURTLE TRANSPORT

16.10.1 Hatchlings, Post-Hatchlings, and Juveniles

Hatchlings are transported in commercially available plastic containers with lids. Shipping container size varies with the size of turtle being transported (Table 16.2). Ventilation holes are made three-quarters of the way up the side of the container. Size and number of ventilation holes vary with container size. The container is lined with a piece of solid, open-cell foam rubber and moistened with seawater. Carpet underpadding is the preferred foam type for smaller containers and it is available in large rolls, allowing custom-sized pieces to be cut. The amount of saltwater added to the foam varies with turtle and container size. If too little water is added, the turtle will desiccate. If too much water is added, it can cause vehicle motion-related injuries. Hatchlings are particularly sensitive to drowning from too much water, should turtles crawl and rest on top of one another. Shipping container size for turtles >1.0 kg should be large enough to comfortably hold the turtle, but small enough to prevent excessive motion and turning.

All turtles should be shipped in a climate-controlled vehicle (23–30°C) with temperature and moisture checked regularly and adjusted as necessary. Additional moisture can be added using a fine mist from a spray bottle. The number of turtles per shipping container should be reduced for long trips. Containers should be stacked not more than three high to prevent them from tipping over during normal vehicle movement. If possible, the use of straps and/or cargo nets is recommended when transporting turtles by aircraft.

16.10.2 Subadults and Adults (>15 kg)

Because of their size and strength, subadult and adult turtles can be difficult to transport.

16.10.2.1 Short Distances or Short Time Periods

Not many readily available containers can be purchased off the shelf to transport large turtles. Those that are available tend to be available in small quantities and

TABLE 16.2
Recommended Turtle Shipping Container Size and Water Volume

Turtle Size[a]	Turtle Age (months)[a]	Number Turtles/ Container	Shipping Container Volume (l)	Shipping Container Dimensions (cm)	Foam Dimensions (cm)	Water Volume (l)	Vent Hole Size (cm)/Number
<30 g	<1	80–100	38	50 × 36 × 20	33 × 50 × 1.27	1.0	3.8/8
30–60 g	0–3	1–30	38	50 × 36 × 20	33 × 50 × 1.27	1.0	3.8/8
60–500 g	3–11	1–6	38	50 × 36 × 20	33 × 50 × 1.27	1.5–2.0	3.8/8
0.5–1.0 kg	11–14	1–4	38	50 × 36 × 20	33 × 50 × 1.27	3.0	3.8/8
1.0–5.0 kg	14–22	1	38	50 × 36 × 20	33 × 50 × 1.27	4.0	3.8/8
5.0–25.0 kg	22–48	1	125	74 × 38 × 41	38 × 69 × 1.27	6.0	3.8/10
<40 kg	>48	1	240[b]	61 × 91 × 22[c]	60 × 90 × 5.01	15.0–20.0	5.01/16

[a]On the basis of NMFS STF average Cc and Lk data (1995–2000).
[b]Volume of two containers combined.
[c]Height of two containers combined.

are expensive. For turtles up to 35 kg and 65 cm straight carapace length, a relatively inexpensive shipping container can be made by fastening two plastic concrete mixing trays together with nylon cable ties. The tray that forms the bottom of the container is lined with a piece of saltwater-soaked foam cut to fit. A wet terry cloth towel can also be draped over the carapace and flippers to assist in keeping the turtle from drying out. Excessive evaporative cooling must be avoided, and wet towels should not be used when shipping during cool weather. Coating the carapace and skin with a petroleum-based (Walsh, 1999) (Vaseline®, Cheseborough-Pond's USA Co., Greenwich, CT) or water-based lubricant (KY®, McNeil-PPC, Inc., Skillman, NJ) may help prevent desiccation. The top of the tray is fastened to the bottom with nylon cable ties inserted through 6-mm holes drilled through the top and bottom lips of the two trays. This arrangement does not allow the shipper to easily inspect or replenish water lost during transport, and therefore this shipping method should be reserved for very short trips of 2 h or less, or for unaccompanied air travel.

16.10.2.2 Long Distances

Large turtles can be shipped long distances using readily available rental trucks. The cargo compartment of a rental truck can be subdivided into individual compartments with 19 mm plywood. The cargo bay is lined with a waterproof tarp or plastic to contain moisture and prevent damage to the vehicle. Ten- to 15-cm-thick foam is cut to fit the bottom of the compartment and is soaked with seawater to keep the turtle moist. Additional moisture can be added using a fine mist from a spray bottle directly onto the turtle, and new clean water may be required to replace water lost to evaporation. Transport in this fashion should be limited to trips less than 12 h and when the cargo compartment can be kept between 23 and 30°C. If possible, the turtles should be shipped in darkness to keep activity to a minimum. Some rental trucks have a translucent fiberglass roof, and light transmission through the roof will increase turtle activity.

16.11 GROW-OUT FACILITIES

The NMFS Panama City, FL (NMFSPC), sea turtle holding facilities consist of nine pens and a series of individual holding containers. Stocking densities of loggerhead and Kemp's ridley sea turtles need to be carefully monitored when captive turtles are allowed to interact with one another in a confined environment. Aggressive behavior has also been observed in green (Wood, 1991) and hawksbill sea turtles (Glazebrook, 1990). Although water quality is less of a concern in a pen-type environment, lesions caused by biting and fighting can seriously compromise turtle health. Sea turtles held in pens rarely venture from the sides, thus utilizing only a fraction of the available pen surface area. Construction of pens that maximize perimeter is preferred to pens that maximize open water (Higgins, unpublished data).

16.11.1 Semiwild Conditioning

Prior to use in research projects and before release, NMFS STF loggerhead sea turtles are given a period of semiwild conditioning. Conditioning introduces the turtles to a wild-type environment while keeping them in a controlled and observable space. Kemp's ridleys that are regularly exercised exhibit greater strength and stamina than turtles that are not exercised (Stabenau et al., 1992). Both loggerhead and Kemp's ridleys that are semiwild conditioned for a period of 2–4 weeks appear to have increased strength and stamina compared to unconditioned turtles (J. Mitchell, personal communication).

16.11.1.1 Conditioning–Rearing Pens

Large pens have been constructed at the NMFSPC facility to accommodate up to 200 sea turtles that are 2 years old. The pens range in size from 92 to 223 m^2 and 0.76 to 2.1 m deep. The pens are framed with treated wooden pilings and metal pipe covered with either vinyl-coated metal wire mesh or plastic Durethene® (ADPI, Philadelphia, PA) mesh. The pens are lined on the inside bottom perimeter with a skirt of vinyl-coated metal wire to keep the turtles from burrowing under the pen walls (Figure 16.5). Various walkways, bulkheads, and docks provide access to the pens. The pens contain a natural bay bottom, including sand, seagrass, shell rubble, and rock. The bulkhead walls and mesh sides contain a variety of biota, including algae, barnacles, oysters, sponges, soft corals, tunicates, and various species of cnidarians, echinoderms, fish, crabs, shrimp, and mollusks.

After transportation, the turtles are given a 24-h acclimation period prior to introduction into the pens. A series of independent basins equipped with a flow-through seawater system is used for acclimation, for holding aggressive turtles, and for treatment/observation of problem turtles. The basin system consists of plastic laundry tubs in groups of 10–21 connected to a common drain with water level maintained by an adjustable standpipe. Seawater is delivered by submersible (0.5 hp) pumps feeding an incoming line of valves. Each incoming water valve supplies water to two basins at a variable rate of 150–227 l/h. The basins are housed in a structure shading them from direct sunlight (Figure 16.6).

16.11.1.2 Temporary Holding Facilities

Unfiltered flow-through seawater systems should be avoided. Larvae in the water will settle in and on the pipes, rearing containers or tanks, and sea turtles. At NMFSPC, barnacle larvae settle on the carapace, plastron, and skin of the loggerheads in unfiltered flow-through seawater systems. This problem is confined to the holding tanks and is rarely observed on turtles in the pens. Although epibiota are common to wild loggerheads (Frick et al., 2000), turtles maintained in confined spaces are susceptible to rapid fouling. Rapid turtle growth is common during conditioning. As turtles grow, new carapace tissue is laid down between the scutes (suture lines). This new tissue is easily distinguished by color, and is often accompanied by an attractive striated pattern. Barnacles settling on this new tissue are able to penetrate deeper than on older tissue, and with heavy infestation will lift the edges

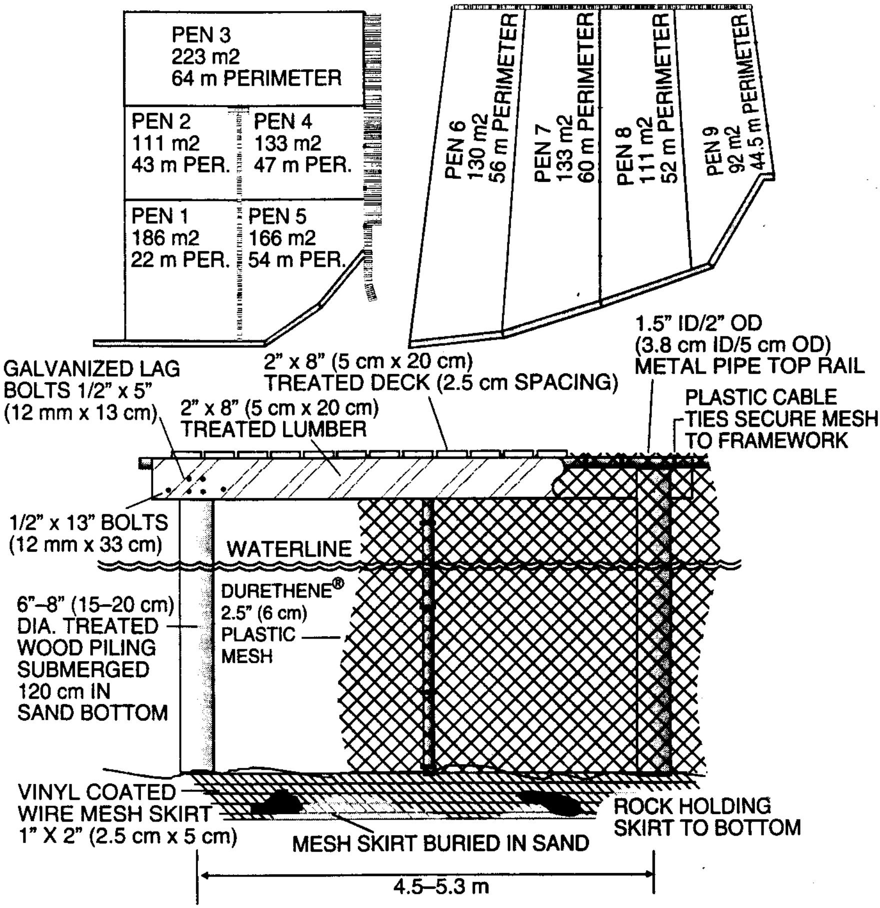

FIGURE 16.5 Panama City, FL, pen-holding facilities. Many other sea turtle rearing facilities use pens or fenced off areas for at least part of the rearing period.

of the scute, causing lesions and infection. Barnacle larvae can settle and lift scutes in as little as 10 days. Barnacles are removed from sea turtles with a stiff brush or plastic scraper as soon as they become visible to the naked eye. Lesions are treated topically with chlorhexidine (chlorhexidine gluconate 2%). Oyster larvae will settle on captive sea turtles, but without the same damaging effects as barnacles. Turtles that are maintained in shallow water and confined spaces in full sunlight will rapidly grow a thick coat of algae on all dorsal surfaces. Turtles should be given deep enough water and ample space to move about to minimize algae buildup. Algae are scrubbed from the turtles every 30 days during conditioning and just prior to release.

16.11.1.3 Feeding

Turtles are allowed to forage naturally in the pens, and they are offered thawed, frozen squid at a rate of 5–10% average body weight/day. Fish that are naturally

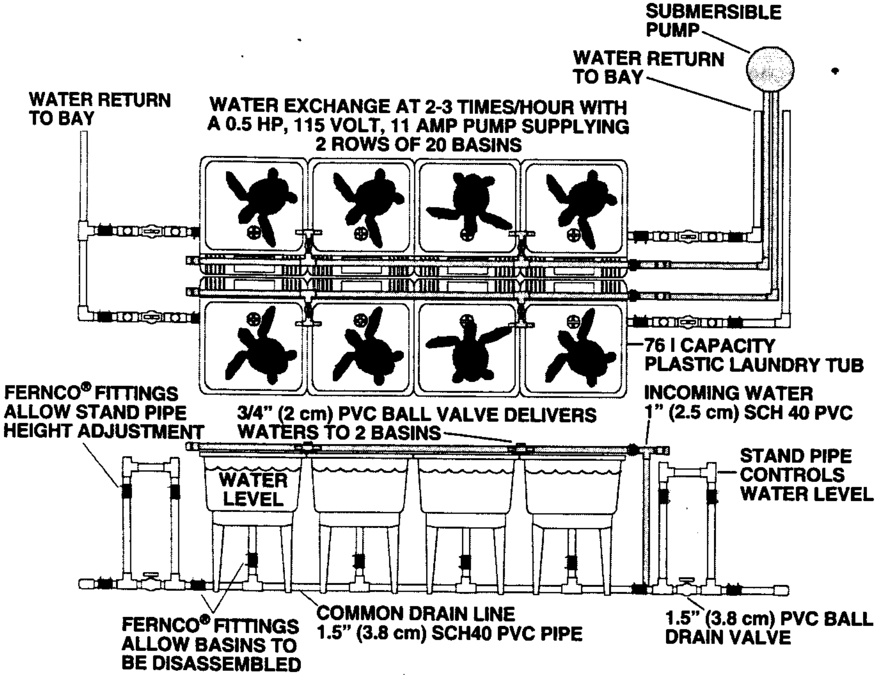

FIGURE 16.6 Temporary basin-holding system at the Panama City, FL, facility. The system can be broken down for storage and expanded to hold additional turtles (Fernco®, Fernco, Inc., Sparks, NV).

present in pens consume a significant portion of the food offered, depending on sea turtle activity. More than the target 5% is offered to compensate for competition from fish. Large squid are cut to facilitate feeding of smaller turtles. Turtles in pens have been observed catching and eating fish, barnacles, and crabs. Often, turtles kept in pens will be returned to a tank or basin system, if significant amounts of sand, rock, and shell debris are found in the feces. Whether the turtles consume the rock and sand along with food or prey items or whether they eat these items for another purpose is unknown.

16.11.1.4 Behavioral Problems

Occasionally, loggerheads and Kemp's ridleys reared in isolation, when placed together, will fight. What triggers the fighting is unknown. Stocking density, water clarity, water temperature, tidal level, wave action, and the presence of other animals in the pens have been investigated in an attempt to isolate the cause of fighting. Thermal stratification and temperature inversions in the pens can force the turtles into a single plane of water, crowding the turtles at the surface or on the bottom. In any large group of loggerheads, there will be a few turtles that cannot coexist with other turtles. If these aggressive turtles can be identified and removed from the general population early in the stocking phase, fighting can be reduced or even eliminated among the remaining turtles. Often, aggressive loggerheads removed for fighting are below average in size or weight, exhibit physical scute anomalies, and may be lighter in pigmentation (blonde loggerhead).

16.11.1.4.1 Aggressive Behavior

Fighting among juvenile loggerheads (20–48 months of age) is manifested as a progressive escalation of aggression. An aggressive turtle will follow another turtle, often at a distance at the bottom or below the surface. The distance soon closes, and the pursued turtle accelerates its swimming pace to gain distance. The aggressive turtle will accelerate to match the pursued turtle's speed. The lead turtle will start to circle in an attempt to elude the aggressive turtle. The aggressive turtle will bite at the posterior carapace of the lead turtle, and will progress to biting at the rear flippers. The pursued turtle will come to the surface in an attempt to escape the aggressive turtle. Once at the surface, the aggressive turtle will try to bite the front flippers and neck of the pursued turtle by coming up and over the carapace. The pursued turtle at this point may turn to defend itself, resulting in the turtles' facing one another, plastron to plastron, jaws locked with heads and fore flippers out of the water. Considerable splashing and flipper slapping on the surface accompany the final stages of fighting. If the turtles are not separated and removed, severe injury to both turtles will occur.

During the pursuit, incidental contact usually occurs between the two engaged turtles and other turtles in the pens. If the aggressive turtle is not removed at the circling phase, and fighting escalates to the surface, all the turtles in the pen, and occasionally adjacent pens, will become agitated. Agitation advances to contact, resulting in fighting among all turtles in the pen. Removal of all turtles from a pen is sometimes the only remedy to an escalating fighting situation. The majority of the time, if the aggressive turtle can be identified and removed at the circling stage, injuries and collateral fighting can be eliminated.

16.11.1.4.2 Passive–Aggressive Behavior

Aggression in a pen can be detected indirectly. A turtle that remains at the surface, with fore flippers folded on the carapace and head down, nervously scanning from side to side below the surface, is a sure sign that there is an aggressive turtle in the pen. Often, turtles in this defensive stance will not feed. Other turtles in the pen will avoid the turtle exhibiting passive–defensive behavior and may interpret this behavior as aggressive in itself. Early identification, removal, and isolation of aggressive and passive–aggressive turtles is the key to pen harmony.

16.12 HEALTH PROBLEMS OF CAPTIVE-REARED TURTLES

Although histopathological and bacteriological analytical services for sea turtle samples are readily available (Texas Veterinary Medical Diagnostic Laboratory, College Station, TX), it often is necessary to initiate treatment prior to receiving test results. Sea turtles may deteriorate rapidly once a health problem is manifested. On-the-spot diagnosis and initial treatment is often necessary to prevent an epizootic outbreak. Any facility rearing sea turtles should have access to a qualified veterinarian with experience in diagnosing and treating reptiles, specifically sea turtles.

16.12.1 Bacterial and Viral Infections

The most common bacteria species isolated from sea turtle infections include *Vibrio*, *Aeromonas*, *Pseudomonas*, and *Cryptophaga-Flavobacterium* (Glazebrook, 1990; Leong et al., 1989; George, 1997). *Streptococcus*, *Salmonella*, and coliform bacteria have also been identified as pathogens in green, hawksbill, loggerhead, and Kemp's ridleys (Glazebrook, 1990; Leong et al., 1989; George, 1997). Many opportunistic bacteria (*Vibrio, Flavobacterium*) are naturally present in seawater and become pathogenic only when the animals are stressed, injured, or the environmental conditions are compromised (Glazebrook, 1990). *Aeromonas* and *Pseudomonas* may be natural opportunistic flora of the sea turtle, becoming pathogenic when the turtle's health is compromised. Through careful attention to water quality, independent isolated rearing, and a suitable diet, bacterial infections of sea turtles can be reduced to an occasional occurrence or even eliminated. Slow feeding, cessation of feeding, and lethargy are sure signs of a primary or secondary bacterial or viral infection. Identifying, isolating, and treating sick turtles with injectable antibiotics in the early stages of infection greatly increase the odds of recovery.

16.12.1.1 Dermal Lesions

Skin lesions (traumatic ulcerative dermatitis) caused by biting and physical contact with the rearing tank are universal in the culture of all sea turtle species (Glazebrook, 1990; Leong et al., 1989). The most prominent areas of lesions include tips and trailing edges of flippers, neck, and tail. Dermal lesions quickly become infected with bacteria, with morbidity and mortality rates of 30–100% (Glazebrook, 1990). Hatchlings are particularly sensitive to secondary bacterial infections, which can approach epizootic levels in rearing systems where turtles are allowed contact with one another (Glazebrook, 1990). Rearing turtles in independent isolation, in appropriately surfaced, sized, and shaped containers, can virtually eliminate ulcerative dermatitis problems for all species except the leatherback. Captive-reared leatherbacks are susceptible to dermal lesions on the head and fore flippers through contact with rearing container walls (Jones et al., 2000). Attempts to keep leatherback hatchlings from contacting rearing containers to prevent self-inflicted dermal lesions have had limited success (Jones et al., 2000).

16.12.1.2 Eye Lesions

Keratoconjunctivitis–ulcerative blepharitis have been reported in green sea turtles, with symptoms ranging from yellow deposits on the eyelids and cornea to complete erosion of tissues, probably as a result of secondary bacterial infection associated with impact trauma or biting (Glazebrook, 1990). Injuries to the eyes are common when turtles are in contact with one another and when housed in tanks with sharp objects and abrasive surfaces.

16.12.1.3 Respiratory Infections

Bacterial and fungal respiratory infections are not as common as dermal and gastrointestinal infections (Glazebrook et al., 1993; Leong et al., 1989) in sea turtles, but should be suspected if a turtle is lethargic and floating on its side. Tilted-swimming or side-floating turtles should be quarantined immediately because respiratory infections (bacterial and fungal) are most often fatal and may be contagious. Leong et al. (1989) described mycobacterial pneumonia (MP) infections as a cause of tilted-swimming, and found that antibiotic treatment of MP with streptomycin was ineffective. The NMFS STF has been identifying and treating tilted-swimming turtles with 5 mg/kg injectable enrofloxacin (Baytril®, Bayer Corp., Shawnee, KS) with promising results. Although an MP or fungal infection is suspected, in most cases, limited attempts are made to isolate the infectious agent because of the intrusive nature of obtaining samples from the lungs. The MP or fungal infection may be secondary to a bacterial pneumonia infection.

16.12.1.4 Viral Infections and Gray-Patch Disease (GPD)

The herpesvirus is believed to cause cutaneous lesions on the flippers and neck of green sea turtle hatchlings. At the Cayman Turtle Farm, GPD has been reported to infect 65–95% of green turtle hatchlings. Although it appears to be cutaneous in nature, infecting only the epidermal layers, it can be fatal (Haines, 1978; Haines and Kleese, 1977). GPD occurs in two forms: pustular-like (blister) lesions that resolve spontaneously with time, and extensive gray-patch lesions that may spread to cover large areas of skin (Haines, 1978). The latter form is often lethal (Haines and Kleese, 1977).

Recovery from pustular GPD results from spontaneous healing by the time the turtles reach 12 months of age (Haines, 1978). Poor water quality, most notably elevated water temperature (>30°C), and overcrowding (stress) may trigger the manifestation of both forms of GPD. Infection rates and severity vary with age, with hatchlings being most susceptible (Glazebrook et al., 1990; Leong et al. 1989; Haines, 1978).

16.12.2 Bloating–Floating

Loggerheads fed a commercially prepared pellet diet can develop floating–bloating problems even at levels not considered to be overfeeding. Overfeeding Kemp's ridley hatchlings or post-hatchlings can cause bloating (Fontaine et al., 1985). Pelagic loggerhead hatchlings and yearlings are the most susceptible to the condition, and the condition is exacerbated by low water temperature and a short photoperiod, with the problem being more prevalent in the winter months. The exact cause is unknown, and no bacterial or viral pathogens have ever been isolated. Permanent carapace and plastron deformation occurs with growth. The problem can become chronic without treatment. Increasing the size of the rearing container volume (a minimum of three times), increasing water depth (a minimum of two times), temporarily switching the diet from pellet food to squid or fish, offering the turtle a tube (15 cm diameter PVC × 31 cm long) in which to hide and/or hold itself down on the bottom, increasing water temperature, and increased artificial illumination has proved to be an effective rehabilitation regime, with a success rate exceeding 90% (Higgins and Bustinza, unpublished data). Attempts have been made to treat the condition by manipulating just one or two treatment parameters without success (Higgins and Bustinza, unpublished data).

16.12.3 Carapace Lesions

Leong et al. (1989) describes two forms of carapace lesions: dull-white suture (DWS) syndrome, and shiny-white suture (SWS) syndrome, both common on young captive loggerheads. Both DWS and SWS are described as ribbons of white material along the suture lines. Microscopic examination of the white ribbon material identified debris, bacteria, and *Fusarium*-like fungal spores. No effective treatment was described by Leong et al. for SWS, aside from maintaining good water quality.

Periodically, NMFS STF loggerheads develop something similar to what Leong et al. describe as SWS, and for future reference, this condition will be referred to as fluffy-white suture syndrome (FWSS). FWSS is first manifested by fluffy-white material appearing on the posterior edge of the carapace scute spines. In severe cases, the suture lines become covered with the fluffy-white material similar to the description of Leong's SWS. Left untreated, the FWSS lesions expand to cover large areas at the center of the scute, resulting in a rough circle of damaged tissue. Keratin damage with exposure of the underlying epidermis and bone follows.

Histological examination of scrapings taken from infected turtles revealed no bacteria or fungal presence; the white material is described simply as an exudate with debris. Oral and injectable treatments with enrofloxacin and topical applications of Vagisil® (Combe, Inc., White Plains, NY), Betadine® (the Purdue Frederick Company, Norwalk, CT), povidone iodine (10% topical solution, 1% available iodine), and Neosporin® (Warner-Lambert Consumer Healthcare, Morris Plains, NJ) proved to be ineffective, with the FWSS exudate returning in as little as 10–14 days (Higgins, unpublished data). Regular debriding of infected areas twice per week with a scrub brush, followed by the application of strong tincture of iodine (7%) with a paintbrush, followed by 15–30 min of air drying reduced the visible signs of the infection, but keratin and bone regeneration was slow. Debriding followed by applications of a 50% solution of chlorhexidine gluconate (2% solution) with a spray bottle or paintbrush has been very effective, followed by temporary isolation of the turtle and treatment of the rearing water with 10.5 ml/l chlorhexidine gluconate. Early detection of lesions and prompt treatment are critical when dealing with large numbers of turtles sharing a common water source. In serious cases of keratin loss and bone degeneration, topical treatment with antibiotic creams followed by covering the lesions with a protective epoxy coating has proved to be effective (Neiffer et al., 1998).

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